

AMENDED SPECIFICATION

Reprinted as amended under Section 8 of the Patents Act, 1949.

PATENT SPECIFICATION

586,100



Convention Date (Switzerland): Dec. 30, 1943.

Application Date (in United Kingdom): Dec. 8, 1944. 24597/44.

Complete Specification Accepted: March 6, 1947.

By a direction given under Section 17(1) of the Patents Act 1949, this application proceeded in the name of SULZER FRÈRES SOCIÉTÉ ANONYME, a Company organised under the laws of Switzerland, of Winterthur, Switzerland.

COMPLETE SPECIFICATION

Improvements in or relating to Rotors for Centrifugal Compressors

I, CHRISTIAN MEISSER, Doctor of Law, Dipl.-Ing., Swiss Citizen, of Chalet Meisser, Davos-Dorf, Switzerland, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to a rotor for a centrifugal compressor, the rotor being of the type in which the flow takes place over a substantially conical surface generated by a straight or curved line and is helically guided with respect to the rotor axis by means of blades, the blades being bent backwards in a screw shape and having peripheral boundary lines derived from meridian lines on the rotor varying from flat to concave.

According to this invention the screw pitch of the blades is uniform both on the pressure and on the suction flanks of the blade, and the pitch of the blade surface on the pressure flank is by so much less than the pitch of the surface at the suction flank, that the blade thickness at the blade inlet is approximately the same as at the blade outlet.

Preferably the rotor blades are of uniform width along the tip or ridge from the inlet position to the outlet. In preferred forms, and in particular in rotors for high and extra-high peripheral speeds of 400 meters per second and more, the blades may extend radially with respect to the rotor axis in planes at

right angles to the rotor axis and have a profile giving approximately uniform strength. To improve the flow conditions at the rotor outlet the blades may be sharpened to a stream-line shape at the outlet ends. This stream-lining sharpening increases particularly the uniformity of distribution of the velocity over the cross-section of flow, when it is effected at the tip and at the root on the suction flank and at the middle portion on the pressure flank.

One example of a construction according to the invention is represented on the accompanying drawing, in which:—

Figure 1 is a side view of a rotor.

Figure 2 is a diagrammatic view, partly in longitudinal section, of a profile milling machine suitable for making the rotor.

Figures 3 and 4 are cross-sections showing details of the rotor.

The rotor shown in Figure 1 has screw-shaped blades 2, which are backwardly bent with respect to the direction of rotation A and their boundary lines 3 are derived from the meridian lines 4 on the rotor, these lines running flat or concave. Because of the backward bending of the blades 2, there is attained at the outlets 6 a reduction in the absolute outlet speed of the medium compressed. This prevents the absolute velocity at the outlet, in spite of the high peripheral velocity of the rotor 1 at the outlet 6, from reaching the velocity of sound at

the outlet and this prevents the occurrence of Mach pressure waves which would impair the efficiency. At the inlet the tangent at the root of the rotor blades 2 make with the tangent at the rotor surface in the plane of rotation and angle α_1 of about 60° and at the outlet an angle α_2 of about 45° .

Both the pressure flank 7 and the suction flank 8 of the blades 2 are formed as screw-surfaces with a uniform pitch. The pitch of the blade-surface of the pressure flank 7 is smaller than that of the blade-surface of the suction flank 8. The difference in pitch is chosen in such a way that the width of the blade tip is approximately the same at the blade inlet as at the blade outlet. In this way, not only is the construction of the blade simplified, but also the flow conditions along the blades are considerably improved. The difference between the pitch of the blade surface at the pressure flank and that at the suction flank amounts to between 1 and 4% of the pitch, depending on the ratio of the inlet diameter to the outlet diameter. When the difference in diameter is great, this percentage amount will be greater than when the difference in diameter is small. For instance, when the ratio of the inlet diameter to the outlet diameter is 1:2, the percentage amount may be in the neighbourhood of 1-2%. One and the same rotor may be employed for different working conditions, when it is preceded at the inlet end by different preliminary rotors designed to suit the actual working conditions at the moment.

The width of the blade along the ridge between inlet and outlet is preferably kept at least approximately uniform. This gives the advantage that the rotor can easily be designed so that the cross-sectional area of the flow passages formed by the blades 2 remains always constant. The flow area of these passages is the product of the passage depth and the passage width measured perpendicularly to the passage direction. This latter is the circumferential passage width measured in the plane of rotation multiplied by the sine of the angle of inclination α between the blade direction and the rotor circumference at that point. The circumferential width is equal to the circumference divided by the number of blades (circumferential pitch) minus the blade thickness measured in the plane of rotation. The flow area is thus ultimately determined, for a given number of blades and an angle α changing according to the laws imposed by the profile milling machine, by the thickness of the blades and the passage

depth. It is clear that it is much easier to design the passage depth so as to keep a constant flow area if the blade thickness is at least nearly constant, than if it changes abruptly, the more as the passage depth is also determined by design considerations in respect of flow contours and easy machining of the template 25 (Figure 2). The uniformly minimum surface along the ridge of the blades 2 has also the advantage of keeping to a minimum the friction in the boundary layer of the flowing medium confined between the ridge of the blade and the rotor casing. Also for considerations of strength it is advisable to keep the width of the ridge of the blades uniform along the whole length of the blades.

The relative positions of the screw surfaces of the pressure flank and of the suction flank of one and the same blade 2 are chosen in such a way that blade cross-sections at right angles to the axis of the rotor extend radially, and are therefore subjected by centrifugal force only to tensile stresses and not to bending stresses. In order to reduce the tensile stressing, the rotor 1 has no bore for the shaft 9 which is attached to the rotor 1 by a flange. At the outlet 6 the blades 2 are sharpened to a stream-line shape, and a uniform distribution of the velocity of flow can be obtained by the end of the suction flank of blade being sharpened at the tip and at the root, whilst the end of the pressure flank of the blade is sharpened at the middle portion.

The profile milling machine shown in Figure 2 has a bed-plate 11 with two columns 12 and 13. The lead screw spindle 14 is carried in the plain bearing 15 in column 12 and has a screwthread 16 passing through the nut 17 in the column 13. On the spindle 14 is fixed the toothed pinion 18 and the guide bush 19. The driving shaft 20 is carried in the plain bearings 21 in columns 12 and 13. On the driving shaft 20 is fixed the toothed wheel 22, meshing with the pinion 18, and the sliding bush 23 is also arranged on the shaft 20. On the bushes 19 and 23 is carried the control bar 24, which can slide between parallel guides (not shown in the drawing), and this bar is fitted with a copying template 25. On the column 13 is the headstock 26 which can be moved vertically on the guide 35 and horizontally along the guide 35. The headstock 26 is fitted with a guide roller 27 and the motor 28 which drives the milling cutter 29. On the two-piece shaft 20 between the column 13 and the control bar 24 is fixed the blank 30 which

is to be machined to form the rotor.

The process of making the blading 31 on the rotor blank 30 can be performed as follows by means of the profile milling machine shown in Figure 2. At first the shaft 14 with its lead screw 16 is in the starting position at the right-hand side in Figure 2. The toothed-wheel gear 18, 22, the control bar 24 and the shaft 20 with the rotor blank 30 fixed on it are therefore also in their end positions at the right, whilst the roller 27 and the headstock 26 are in their highest positions. If the shaft 14 turns, both it and the toothed pinion 18 and the guide bush 16 are pushed to the left (Figure 2). This axial displacement is transmitted by the control bar 24 to the shaft 20 and is also performed by the toothed wheel 22 and the rotor blank 30. The pitch of the blades is determined by the pitch of the lead screw 16 and the ratio between the toothed wheels 18 and 22. It will be appreciated that different gears 18 and 22 are necessary for milling the pressure and suction flanks of the blades, the screw surfaces of which have different pitches. The axial displacement of the control bar 24 causes the template 25 to press on the guide roller 27 of the headstock 26, so that the milling cutter 29 moves vertically in accordance with this template. By the turning of the shaft 14 the shaft 20 with the rotor blank 30 is also caused to rotate through the toothed gear 18, 22, and in this way a screw-shaped groove of constant pitch is milled out. On the rotor blank with its diameter decreasing from a large to a small value, it is evident that in this case the angle which the blade makes with the peripheral direction increases from a minimum value at the greatest diameter to a maximum value at the smallest diameter. Preferably the ratio of the axial displacement of the shaft 14 to the angle of rotation of the shaft 20 is chosen in such a way that the angle made by the blade with the peripheral direction amounts to about 45° where the diameter of the rotor is greatest and to about 60° where the diameter is smallest.

Considerations of solid geometry show that for certain diameter-ratios at the inlet and outlet ends 5, 6 of the rotor 1 and for certain meridian lines 4, it is necessary to displace the axis of the milling cutter with respect to the axis of the rotor in order that the ridges of the blades may be of uniform width over their whole length. This displacement can also be used with advantage to provide favourable conditions for cutting the tapered milling profile, as is the case with vertical milling cutters with a small

angle of taper.

In Figure 3 of the drawings a vertical milling cutter 29 is employed which has a double taper angle β amounting to about 15° and this gives technically advantageous conditions for the cutting. When milling the blade surface of the pressure flank 7 with respect to the direction of rotation A of the rotor, the axis 32 of the milling cutter is displaced forwards in the direction of rotation with respect to the rotor axis by a definite amount, for instance by 20 mm. in the case of a rotor with a diameter of 30 cm. at the inlet and 60 cm. at the outlet. For milling the blade surface of the suction flank the axis 32 of the same milling cutter 29 is displaced backwards by the same amount with respect to the rotor axis.

By foregoing the possibility of choosing the ratio of the diameters at the inlet and outlet ends of the rotor as well as the meridian lines of the rotor in some desired manner, i.e. in accordance with some technical considerations to favour the flow or to facilitate construction, the blades of the rotor may be constructed by simplified milling methods with the ridge of the blades of approximately uniform width over their entire length. As illustrated in Figure 4, the milling operation of the blade surfaces of the pressure and suction flanks 7 and 8 is effected without any displacement of the axis 34 of the cutter 33 which remains directed towards the rotor axis. The double milling cutter angle γ amounts in this case to 30° and more.

British Patent No. 567,368 relates to a rotary centrifugal compressor of the type which gives extra high pressure ratios per stage, the impeller having blades integral with the rotor and with at least its greatest circumference rotating at a velocity above the speed of sound in the medium compressed, the blades of the rotor when considered in cross sections normal to the rotor axis being radially directed with the object of reducing bending stresses. The patent claims a centrifugal compressor of the type indicated in which the blades run obliquely and at an inclination with respect to the axis of the rotor being curved in the form of a helix from inlet to outlet in the direction opposite to that in which the rotor rotates so that the absolute velocity of the medium compressed does not exceed the speed of sound in the medium so far as to give rise to Mach's pressure waves.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to

be performed, I declare that what I claim is:—

1. A rotor for a centrifugal compressor wherein the flow takes place over a substantially conical surface generated by a straight or curved line and is helically guided with respect to the rotor axis by means of blades, the blades being bent backwards in a screw shape and having peripheral boundary lines derived from meridian lines on the rotor varying from flat to concave, in which the screw pitch of the blades is uniform both on the pressure and on the suction flanks, the pitch of the blade surface on the pressure flank being by so much less than the pitch of the surface of the suction flank, that the blade thickness at the blade inlet is approximately the same as at the blade outlet.

2. A rotor for a centrifugal compressor as claimed in Claim 1, in which the rotor blades are of at least approximately

uniform width along the tip or ridge from the inlet to the outlet over the whole length of the blades.

3. A rotor for a centrifugal compressor as claimed in Claim 1, in which the blades in planes at right angles to the rotor axis extend radially with respect to that axis and have a profile giving approximately uniform strength.

4. A rotor for a centrifugal compressor as claimed in Claim 1, having the blades sharpened to a stream-lined form at the outlet end.

5. A rotor for a centrifugal compressor as claimed in Claim 4, in which the stream-lined sharpening of the outlet end of the blades is effected at the tip and at the root on the suction flank, and at the middle portion on the pressure flank.

Dated this 8th day of December, 1944.

KILBURN & STRODE.

Agents for the Applicant.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1950.

Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies, price 2s. 0d. each (inland) 2s. 1d. (abroad) may be obtained.

[This Drawing is a reproduction of the Original on a reduced scale.]

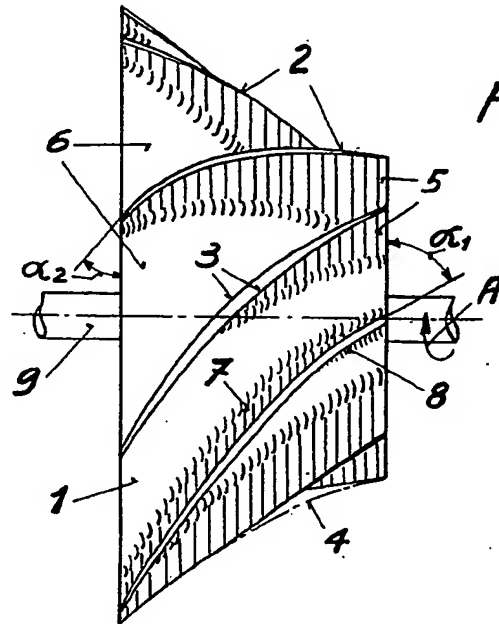


Fig. 1.

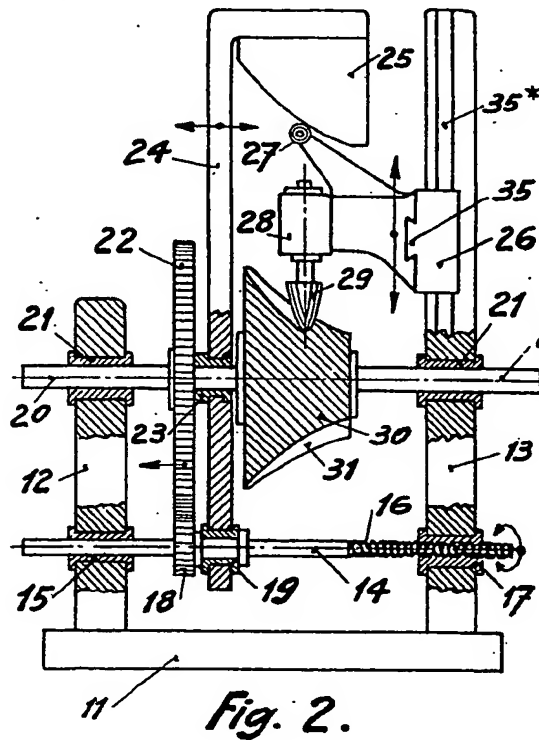


Fig. 2.

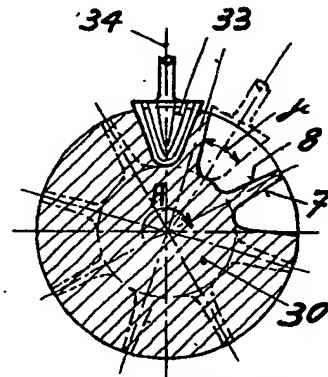


Fig. 4.

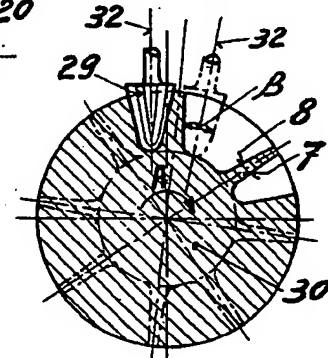


Fig. 3.

THIS PAGE BLANK (USPTO)

United States Patent [19]
Katayama et al.

[11] **Patent Number:** **4,720,243**
[45] **Date of Patent:** **Jan. 19, 1988**

[54] **IMPELLER OF CENTRIFUGAL FLUID-TYPE
ROTARY MACHINE**

[75] **Inventors:** Kazuo Katayama; Susumu Izaki;
Ken Fujita, all of Hiroshima, Japan

[73] **Assignee:** Mitsubishi Jukogyo Kabushiki
Kaisha, Japan

[21] **Appl. No.:** 909,639

[22] **Filed:** Sep. 22, 1986

Related U.S. Application Data

[62] **Division of Ser. No. 839,360, Mar. 13, 1986.**

[51] **Int. Cl.⁴** F04D 29/22

[52] **U.S. Cl.** 416/188; 416/186 R

[58] **Field of Search** 416/183, 185, 188, 242,
416/186 R, DIG. 2

[56] **References Cited**

U.S. PATENT DOCUMENTS

1,959,703 5/1934 Birman 416/183
2,407,469 9/1946 Birman 416/188 X
2,465,671 3/1949 Van Millingen et al. 416/188
2,480,807 8/1949 De Vlieg 416/188
2,782,691 2/1957 Feagans 416/188 X
2,962,941 12/1960 Stein et al. 416/183 X

2,985,952 5/1961 Nutter et al. 416/188 X
4,594,052 6/1986 Niskanen 416/185

FOREIGN PATENT DOCUMENTS

594537 11/1947 United Kingdom 416/183
594538 11/1947 United Kingdom 416/183

Primary Examiner—Everette A. Powell, Jr.
Attorney, Agent, or Firm—McGlew and Tuttle

[57] **ABSTRACT**

An impeller of a centrifugal fluid-type rotary machine includes impeller blades each having a concave and convex surface of which the shape is formed of parallel generatrices inclined with respect to a rotary shaft by an angle defined for each impeller blade. A method of manufacturing the impeller includes inclining a main plate material of the impeller with respect to a plane of a table of a machine tool by a desired angle, fixedly mounting the plate on the table after placing the plate on a rotation indexable jig, controlling three axial positions of the plate in the right and left, front and rear and upper and lower direction by a three-axis controller and cutting out the main plate or side plate by a cutting tool to integrally form the impeller blades on the plate.

1 Claim, 15 Drawing Figures

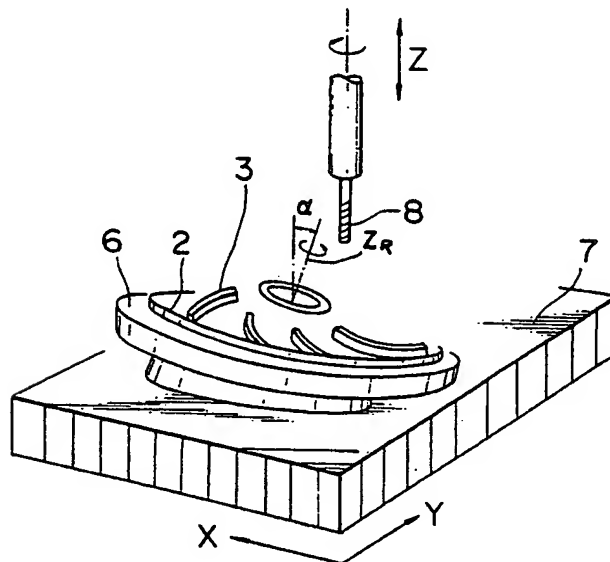


FIG. 1

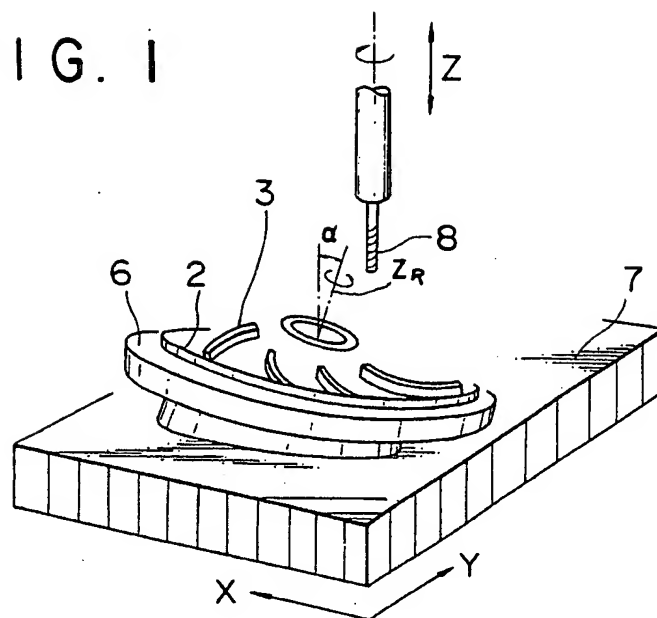
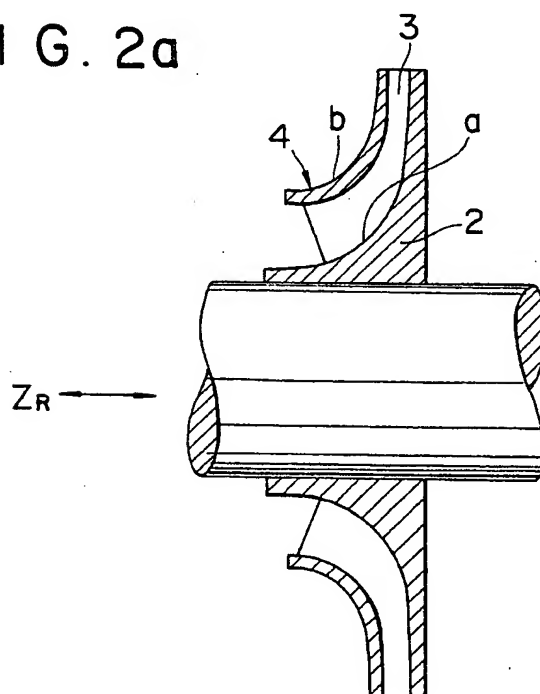


FIG. 2a



BEST AVAILABLE COPY

FIG. 2b

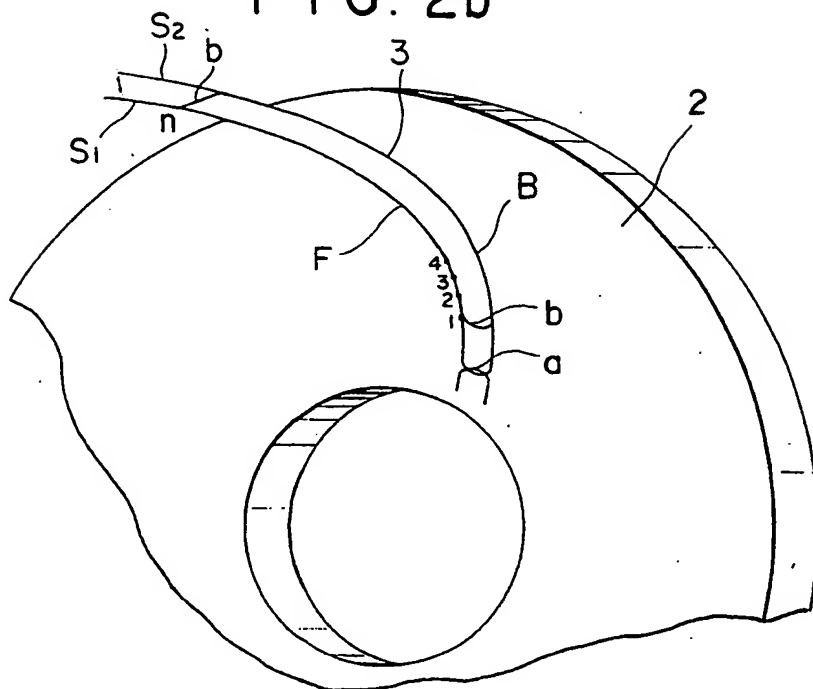
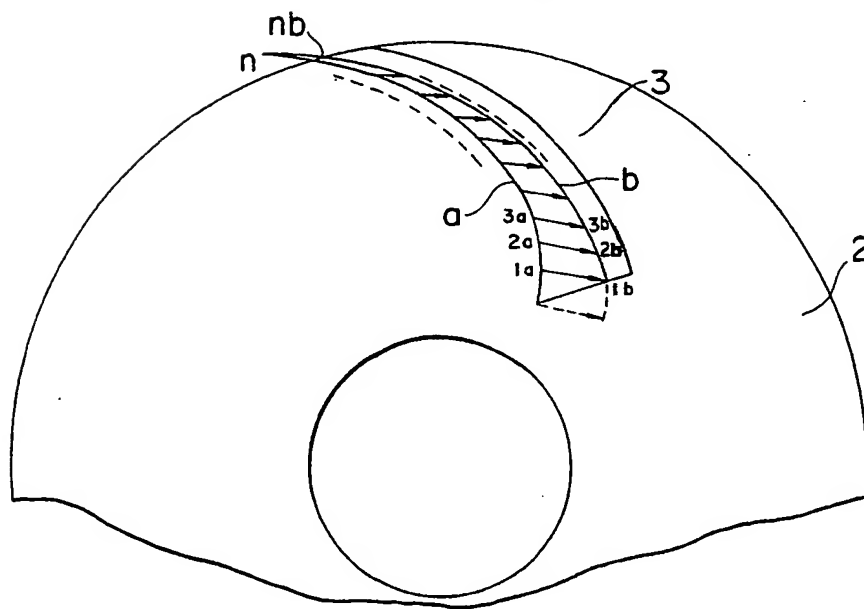


FIG. 3



BEST AVAILABLE COPY

BEST AVAILABLE COPY

FIG. 4

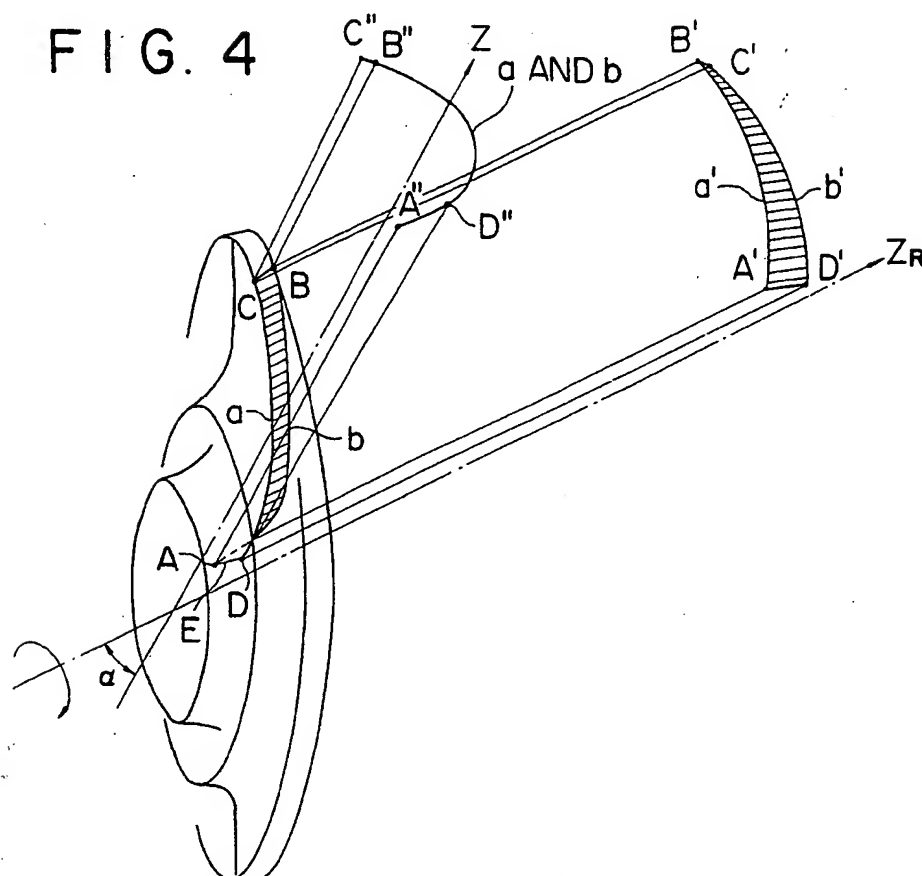


FIG. 5a
(PRIOR ART)

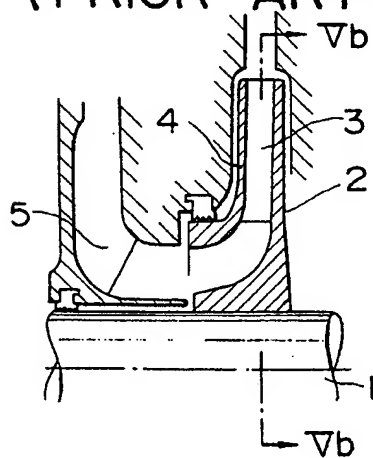
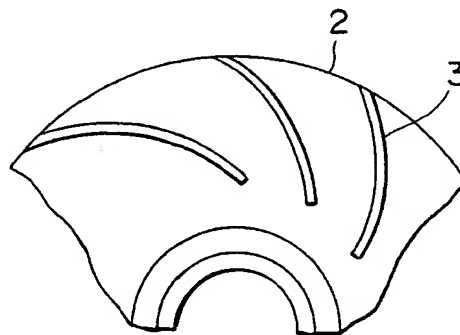


FIG. 5b
(PRIOR ART)



BEST AVAILABLE COPY

FIG. 6a
(PRIOR ART)

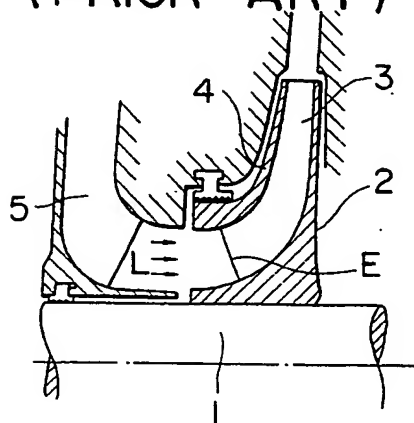


FIG. 6b
(PRIOR ART)

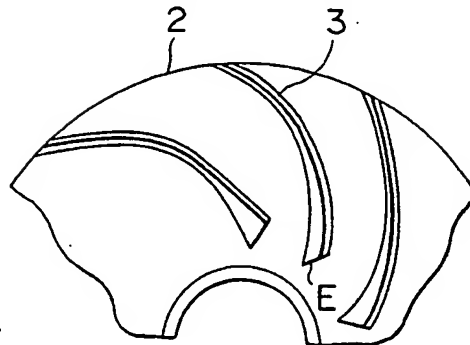


FIG. 7a
(PRIOR ART)

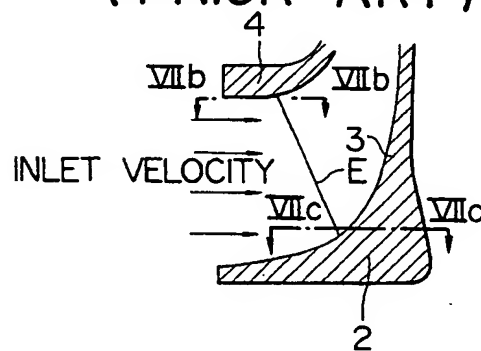


FIG. 7b
(PRIOR ART)

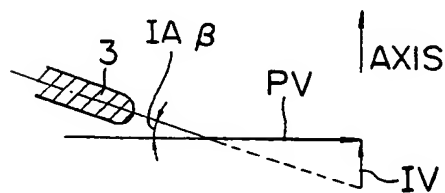
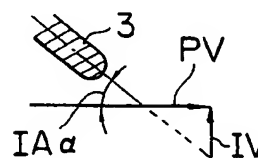
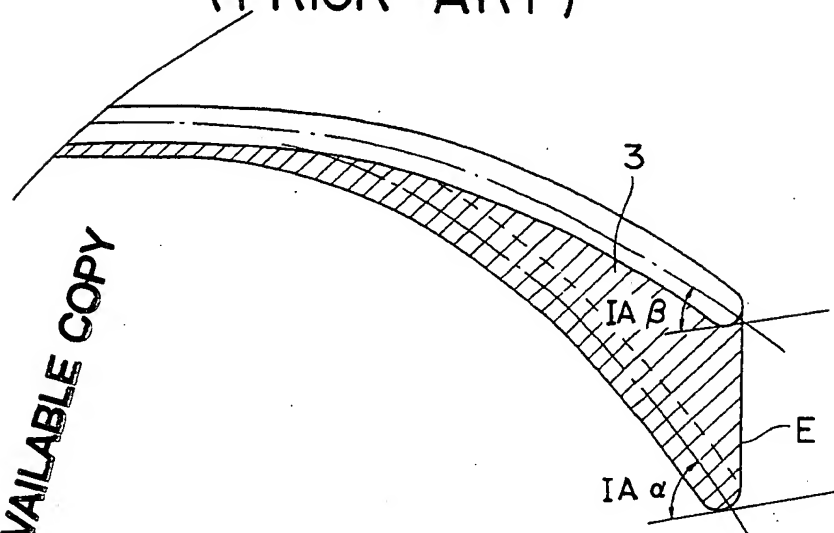


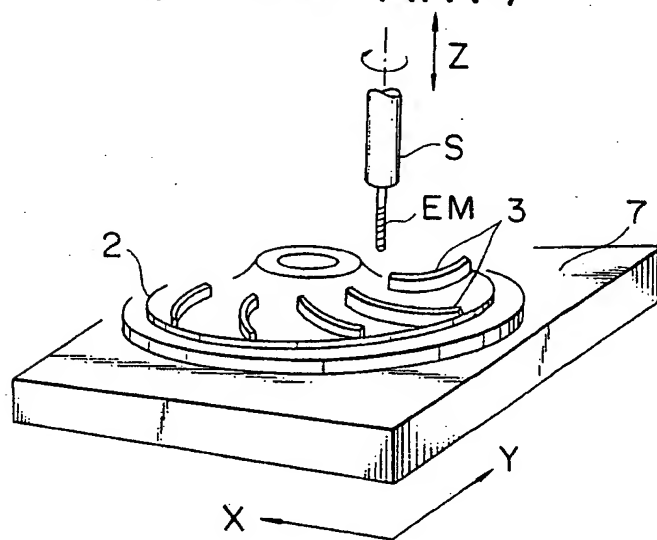
FIG. 7c
(PRIOR ART)



BEST AVAILABLE COPY

FIG. 8
(PRIOR ART)

BEST AVAILABLE COPY

FIG. 9
(PRIOR ART)

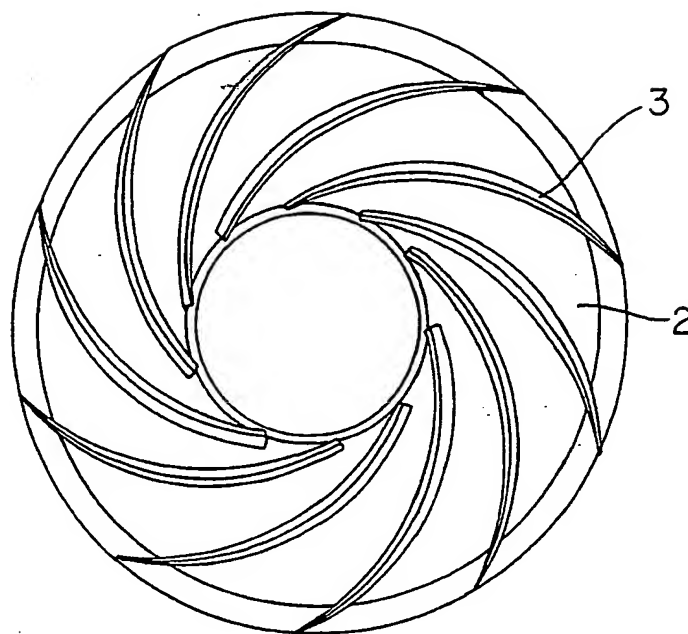


FIG. 10

BEST AVAILABLE COPY

IMPELLER OF CENTRIFUGAL FLUID-TYPE ROTARY MACHINE

This is a division of application Ser. No. 839,360 filed 5
Mar. 13, 1986.

FIELD OF THE INVENTION

The present invention relates to an impeller of a lubricating oil pump for a steam turbine for use in a turbo 10
generator and an impeller of a centrifugal fluid-type rotary machine such as a high-pressure pump, a centrifugal compressor and a centrifugal blower and a manufacturing method thereof.

PRIOR ART

A prior art impeller and manufacturing method thereof will now be described with reference to FIGS. 5 to 9.

FIG. 5a shows a section of an impeller used in a fluid machine such as a pump and a centrifugal compressor including a centrifugal impeller using conventional technique and FIG. 5b shows a section taken along line Vb—Vb of FIG. 5a. Numeral 1 denotes a rotary shaft, 2 a main plate of an impeller attached on the rotary shaft, 3 impeller blades, 4 a side plate, and 5 straightening vanes for introducing fluid into the impeller efficiently.

The prior art impeller rotated at a high speed is manufactured by cutting out the main plate 2 to form the impeller blades integrally thereon and joining the impeller blades 3 with the side plate 4 by rivets or welding. Alternatively, the impeller is manufactured by cutting out the side plate 4 to form the impeller blades 3 integrally thereon and joining the impeller blades 3 with the main plate 2.

The conventional impeller includes the impeller blades all of which are formed in the same shape at any section perpendicular to the shaft as shown in FIGS. 5a and 5b. More particularly, the shape of the concave surface and the convex surface of the impeller blades is formed of the generatrix parallel to the shaft of the impeller. The generatrix is a straight line component involved in a curved surface such as a conical surface, a cylindrical surface and the like. Since the impeller blades have such shape, an end mill cutter EM attached to a movable spindle S which is controlled to be moved in the Z-axis direction, that is, in the axial direction of the impeller perpendicular to the X-Y plane, as shown in FIG. 9, is used to cut out the main plate 2 so that the impeller blades are integrally formed on the main plate 2.

PROBLEMS THAT THE INVENTION IS TO SOLVE

In recent years, various improvements in design have been performed to increase efficiency of the fluid machines. Particularly, improvement in the shape of impeller increases efficiency. One of improvements in design is that an inner top end E of the impeller blades 3 from which fluid is sucked in the impeller blade side is extended to the inner diameter of the shaft as compared with that of the conventional impeller blades (refer to FIGS. 6a and 6b). This aims at reduction of loss due to collision of the inner top end of the blades and fluid by slowing down the peripheral velocity of fluid at the inner top end E of the blades 3 and reducing the relative inlet velocity IV of fluid with respect to the blades

when fluid L, flowing in the substantially axial direction, is introduced to the rotating impeller.

In this case, since radii of the end E of the blades at the side of main plate 2 and at the side of side plate 4 are different, the peripheral velocities PV at the side of main plate 2 and at the side of side plate 4 are different. Accordingly, relative inlet angles IA of fluid at the side of main plate 2 and at the side of side plate 4 are greatly different as shown in FIGS. 7a, 7b and 7c. The surfaces of the blade near the leading edge of the suction side is more deflected from the rotary shaft at the side of the side plate 4, then it is at the side of the main plate 2. In order to suck fluid efficiently with respect to the relative inlet angles IA which are different at the side of main plate 2 and at the side of side plate 4 in this manner, it is necessary to form the impeller blades 3 to have different sections in the axial direction, that is, three-dimensional impeller blades as illustrated by the sectional shape of impeller blades in the axial direction in FIG. 8 in which the side plate 4 is removed. Thus, it is necessary to work the main plate 2 or the side plate 4 so that the impeller blades 3, each having such a complicated shape, are provided at equal intervals in the circumferential direction of the impeller.

Generally, it is impossible to form such an impeller including torsion by using only the working machine having a three-axis controller shown in FIG. 9. A working machine having a so-called five-axis controller is required which can control rotational angles around two axes perpendicular to each other in a plane perpendicular to a rotary shaft of a cutter spindle to rotate the cutter spindle. The working machine having such a complicated controller is very expensive. Accordingly, the cost of products is increased and cheap and efficient products can not be supplied.

It is an object of the present invention to provide an impeller including impeller blades, particularly three-dimensional impeller blades having a shape which can be manufactured by using a working machine with a three-axis controller and a method of manufacturing it.

MEANS OF SOLVING THE PROBLEMS

A first problem is solved by an impeller of a centrifugal fluid-type rotary machine according to the present invention including impeller blades each having a concave and convex surface being formed of parallel generatrices inclined with respect to a rotary shaft by an angle defined for each blade.

A second problem is solved by a manufacturing method of an impeller which comprises mounting fixedly on a table of a three-axis control working machine, a jig which can be rotatably indexed around an axis inclined with respect to a direction of a spindle of the working machine, placing a main plate material of the impeller onto the jig, effecting rotation indexing for each impeller blade, controlling the spindle in three axes to adjust a position thereof and forming integrally impeller blades on the main plate by using a cutting tool.

OPERATION OF THE INVENTION

A plurality of impeller blades to be disposed at equal spacing on a periphery of the impeller are formed for each blade.

The direction of a spindle rotating axis of the three-axis control working machine is Z-axis and a table plate perpendicular to the Z-axis on a plate extending along the X-axis and Y-axis. Which the rotating shaft of the impeller is Zr-axis, the main plate material of the impeller

ler is fixedly mounted on the table plate by using the jig having a rotation indexable mechanism so that the Zr-axis is inclined with respect to the Z-axis by an angle α . The main plate material is rotatably indexed around the Zr-axis. Each of the impeller blades is formed by a cutting tool mounted to the spindle. By fixing the X and Y axes of the spindle and moving along the only Z-axis, a concave surface and a convex surface of each impeller blade can be formed to a cylindroid formed of generatrices parallel to the Z-axis. Other parts of the impeller blade are formed by controlling the spindle in the three-axis direction of the XYZ triad. When formation of one blade is finished, the rotation indexing mechanism of the jig is used to rotate the main plate material around the Zr-axis by a desired angle and formation of a next blade is begun. The main plate 2 does not rotate when each blade is being cut by the cutting tool rotating with the spindle. After the cutting of each blade, the jig 6, on which the main plate is fixed, is indexed or rotated using a rotation mechanism: where the rotation axis Zr of the jig 6 is inclined at an angle α against the spindle axis. The jig rotation axis ZR is identical to the impeller rotation axis Zr.

EMBODIMENT OF THE INVENTION

A method and an impeller manufactured by the method according to the present invention will now be described with reference to the drawings, in which:

FIG. 1 is a perspective view schematically illustrating the disposition of a three-axis control working machine and an impeller when the impeller is manufactured using the method according to the present invention;

FIG. 2a is a sectional view of the impeller manufactured using the method according to the present invention;

FIG. 2b is a perspective view of the impeller seen from the generatrix direction of one impeller blade of the impeller of FIG. 2a;

FIG. 3 is a front view of the impeller of FIG. 2a seen from a rotary shaft direction;

FIG. 4 is a perspective view of the impeller showing the projection of the impeller blade of the impeller of FIG. 2a toward the shaft and the generatrix of the impeller;

FIG. 5a is a sectional view of a impeller manufactured by a conventional technique;

FIG. 5b is a sectional view of the impeller taken along line Vb—Vb;

FIG. 6a is a sectional view of an improved impeller for the impeller of FIG. 5a;

FIG. 6b is a sectional view of the impeller of FIG. 6a;

FIG. 7a is a sectional view of the impeller for illustrating a relative inlet angle of fluid to the impeller of FIG. 6a;

FIG. 7b is a sectional view taken along line VIIb—VIIb of FIG. 7a;

FIG. 7c is a sectional view taken along line VIIc—VIIc of FIG. 7a;

FIG. 8 is a partial enlarged view showing a shape of a blade seen from the shaft direction of the impeller in which a side plate is removed; and

FIG. 9 is a perspective view schematically illustrating the disposition of a working machine and the impeller in a manufacturing method of the impeller by a conventional technique; and FIG. 10 is a front view of the impeller with the side removed.

DETAILED DESCRIPTION

FIG. 2b illustrates an impeller manufactured by the method according to the present invention and seen from a direction inclined by an angle α with respect to the direction of a rotary shaft for a main shaft 2 before a side plate 4 is mounted, in which only one impeller blade is shown and other blades are omitted. The shape of an impeller blade shown by a illustrates a root or base of the main plate and the shape of the blade shown by b illustrates a part corresponding to a root or base of the side plate 4. The shapes a and b of the blade as shown in this manner are overlapped at a certain portion on curves S1 and S2 forming the shape of a back B, that is, a convex surface and a front F, that is, a concave surface and are formed by a part of a common smooth curve. That is, the shapes of the back B and the front F are formed of generatrices perpendicular to the paper on which the drawing is depicted.

Since the generatrices are inclined with respect to the rotary shaft of the impeller by an angle α , the front side of the blade can be seen as shown in FIG. 3 when seen from the direction of the rotary shaft while the back side of the blade can not be seen since the back side hides behind the blade. In this case other blades 3 are omitted. Further, points 1, 2, 3 . . . n on the front surface F of the blade 3 overlapped in FIGS. 2a and 2b are divided into points 1a and 1b, 2a and 2b, 3a and 3b, . . . , na and nb, respectively. The curve shown by points 1a, 2a, 3a . . . na shows the shape of the blade 3 at the root on the main plate and the curve shown by points 1b, 2b, 3b . . . nb shows the shape of the blade 3 at the root on the side plate.

The shape of the impeller manufactured by the method of the present invention is now described in detail with reference to FIG. 4. In FIG. 4 the axes Zr and Z form the horizontal plane for example. A', B', C', D', A'' is the projection of the plane formed with the axes ZR and Y while A'', D'', B'' and C'' is the projection on the plane formed with the axes Z and Y, where Y is the axis perpendicular to the plane formed with ZR and Z.

An intersecting point between the blade 3 and the curved surface of the main plate 2 side at the fluid inlet end E of the impeller blade is A and an intersecting point between the blade 3 and the curved surface of the side plate 4 side is D at the inlet end. A central axis of rotation of the impeller is Zr. For simplicity of explanation, only the front surface side, that is, the concave side of the blade 3 is shown. The description about the back surface is the same as that about the front surface and accordingly the curved surface at the side of front surface is hereinafter referred to as a "curved surface of the blade". In the figure, only one blade is shown for simplicity of the drawing.

A point in which the curved surface of the blade is intersected with the outer periphery of the side surface of the main plate is B and a point in which the curved surface is intersected with the outer periphery of the side plate is C. The curved surface of the blade twisted three-dimensionally in this way is shown by hatched area ABCD in the figure.

When the shape of the blade is projected on a plane perpendicular to the axis in Zr-axis direction, that is, in the axial direction of the impeller, the projected points of the points A, B, C and D are A', B', C' and D', respectively, and the curves a and b in which the curved surface of the blade is intersected with the main plate 2

5

and the side plate 4 are a' and b' , respectively. Thus, the projected curve onto the plane is not coincident.

When the curved surface of the blade is projected on a plane perpendicular to Z-axis, that is, the spindle rotary shaft forming an angle α between Zr-axis and the Z-axis, the points A, B, C and D are projected onto points A'' , B'' , C'' and D'' , respectively, and the curves a and b are projected onto a'' and b'' so that both the curves overlap each other.

The present invention is characterized by the twisted impeller blades constructed by forming the curved surface of the front and back side of the blades by a curved surface which overlaps a curved surface when projected toward the axial direction forming any angle α between the Z-axis and the axial direction.

While the above description has been made for the impeller having the side plate, it will be readily understood that the same method can be utilized for impeller blades which are integrally cut out together with the main plate without the side plate.

EFFECTS OF THE INVENTION

The shape of the impeller blades formed by the above-described working method includes a large inlet angle at the side of the main plate and a small inlet angle at the side of the side plate as shown in FIG. 3. The

6

outlet angle of fluid at the outer peripheral end can be formed to the substantially identical angle for both of the main and side plate. The angle of the impeller blade can be equal to the theoretical inlet angle of fluid at the respective radial positions in the fluid inlet end of the blades by the reason described above and the efficient impeller can be obtained.

An inexpensive impeller with high efficiency can be manufactured using the conventional three-axis control working machine and can be worked in large quantities without great renewal of production facilities.

We claim:

1. An impeller of a centrifugal fluid-type rotary machine comprising a plurality of impeller blades disposed between the main plate and a side plate of said machine symmetrically arranged around said rotary shaft, said blades being formed in a curved shape and having a convex front surface and a concave back surface, said front curved surface and said back curved surface of said blades being formed by parallel geneatrices inclined with respect to said rotary shaft, said blade having edged surfaces with a leading edge at the suction side which is more deflected from said rotary shaft at the outer ends than at their inner ends.

* * * * *

30

35

40

45

50

55

60

65

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

THIS PAGE BLANK (USPTO)